



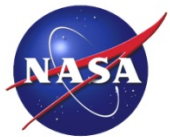
Advanced Mobile Networking Mobile Ad Hoc Networking with IPv6 Sensor Web Overlay

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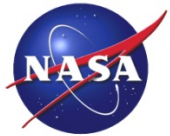
Problem

- Earth Science and Others are interested in ad hoc networks and ad hoc sensor webs
 - What technologies and protocols currently exists that can be applied?
 - Do new technologies and protocols need to be developed?
 - What are the development and deployment issues?
 - How does one secure such a system?



Background

- IPv6 Low Power (6lowpan) Sensor networks are just emerging on the market that can handle ad-hoc networking and some localized mobility.
 - ArchRock® is one supplier of such system
- Cisco System and NASA Glenn had a strong working relationship from initial work on mobile routers and mobile networking
 - Cisco was experimenting with new code called “Duetto” that combined mobile routing and ad hoc networking
 - “Duetto” was totally IPv6 based as it took advantage of IPv6 discovery techniques to quickly build up routing tree structures
 - The nemo portion of the Duetto code exploits the tree to optimally get out of a nested set of Mobile Routers (MRs) and register to the mobile-ip Home Agent.
 - The “Bubbles” protocol has applications in low power sensorwebs for smart buildings, industrial controls and monitoring and has been incorporated into specifications being developed by the Internet Engineering Task Force working group on Routing Over Low power and Lossy networks (roll)



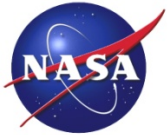
Solution / Approach

- Implement a two-tier sensorweb design.
- The first tier utilized mobile ad hoc network (MANET) technology to provide mobility – the Cisco “Duetto” alpha code.
- The second tier, which is implemented on top of the first tier, utilized 6LowPAN (Internet Protocol version 6 Low Power Wireless Personal Area Networks) sensors – the ArchRock sensors.
- The entire network was IPv6 enabled
- 802.11 radios were used to provide connectivity.
 - Configured in parent/child relationship
 - A Child can connect to only one Parent
 - A Parent can have many Children
 - A Child is prohibited from registering to the Parent that is on the roaming interface of the same MR that the Child is connected to.

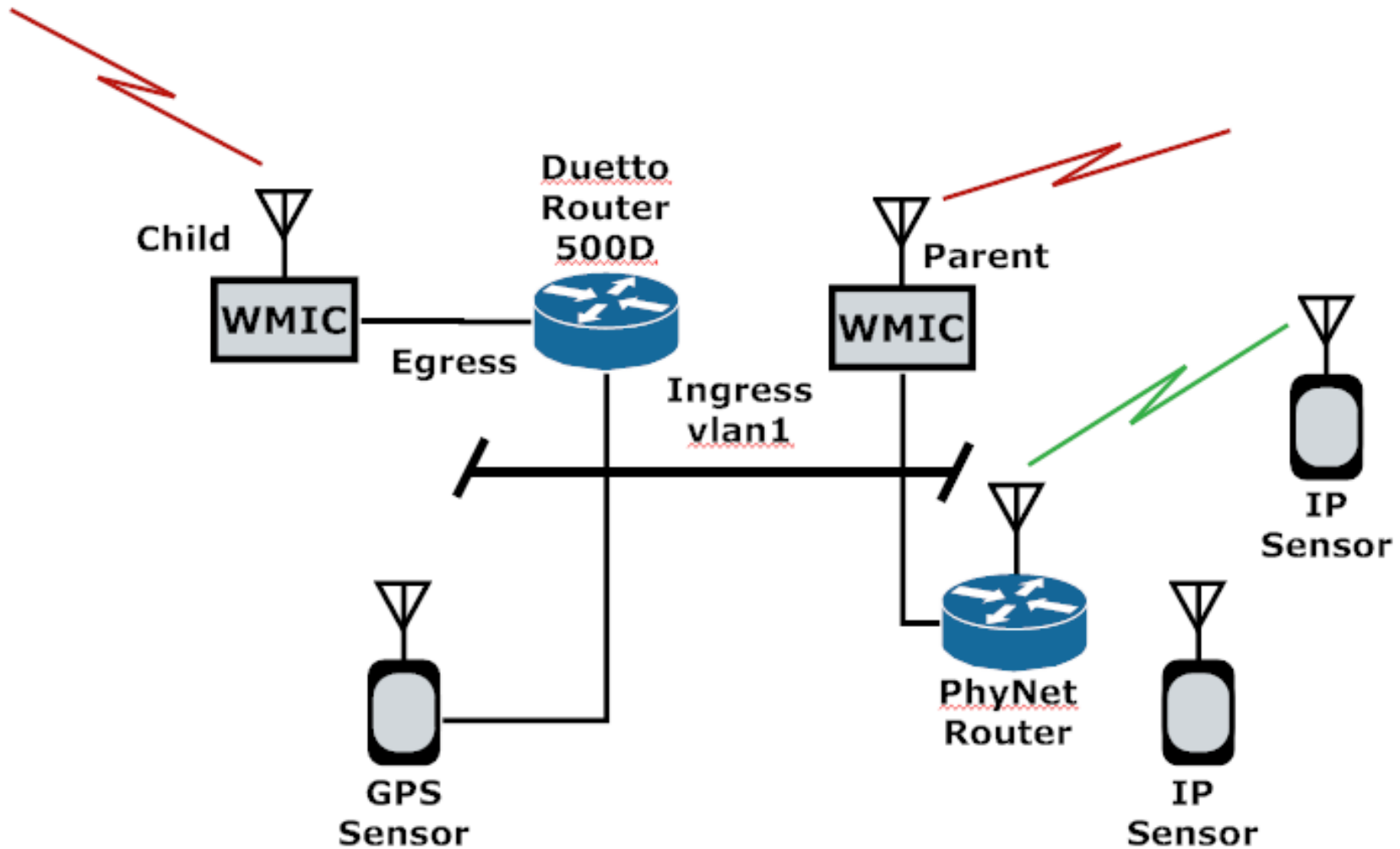


Radios and Manets

- Debugging large radio networks in a small space
 - Self Interference and radio loops
 - Radio Registrations with multiple devices or constant re-registrations
- Multi-homed systems
 - Ingress/Egress connection loops
 - An issue at the network and radio layer
 - Cisco implemented a loop avoidance algorithm in the Tree Discovery process to ensure that the mobile networking software prohibited a single node's egress port(s) from connecting to its ingress port as well as ensure that a Top Level Mobile Router (TLMR)
- We have yet to identify a good radio for use in layer-3 ad hoc networking other than 802.11 used ad hoc mode
 - Ad hoc mode is really mean for peer-to-peer connections more so than ad hoc networks.
 - Layer-2 protocols often counteract rather than compliment layer-3 ad hoc routing protocols

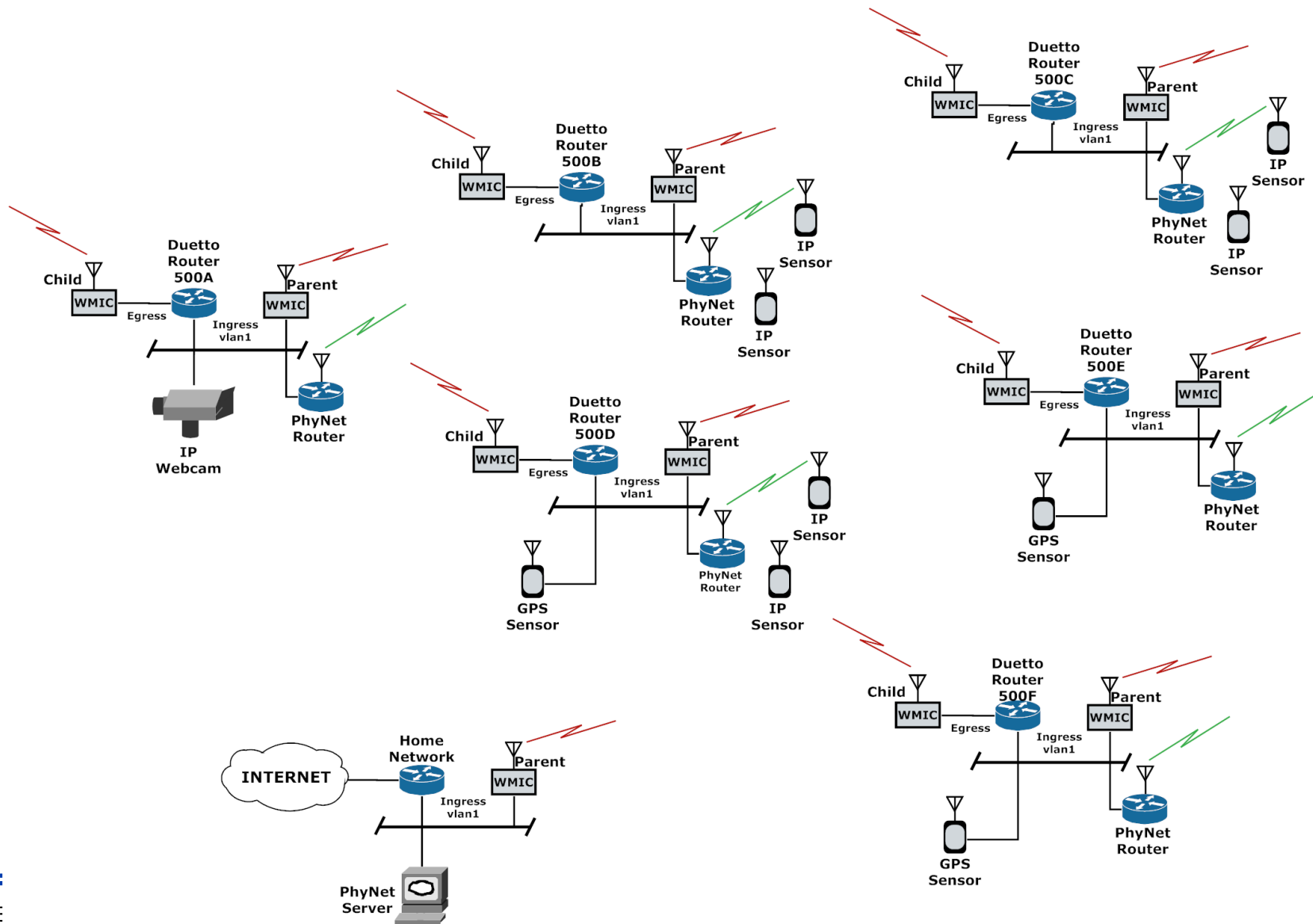


Mobile Sensor





Mobile Sensor Network





IPv6 Issues

- For the Cisco 802.11 radios, the “root bridge” / “working group” pair was the only mode found to work with IPv6. Other Combinations broke the IPv6 stateless auto-configuration, which is necessary for the Duetto protocol.
- The Cisco WMIC cards do not support ad hoc mode
- Wireless Mobile Router Interface Cards (WMIC) cards are not capable of full MANET radio functionality. Bridge-Mode was the only combination found to work (although other modes may work, our exhaustive search found none).
- The ArchRock sensor network operated via IPv6 but had to also have IPv4 addressing.
- The Panasonic IPv6 Camera had to be configure with IPv4 before one could run IPv6.



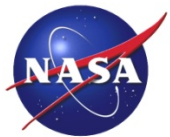
Duetto Routing

- The IPv6 auto configuration on the IOS version used would only work if the subnet of the advertising interface was a /64. Therefore each egress IPv6 interface needed to be configured with a /64 subnet.
- The Duetto code only forwards subnets assigned to its interfaces and any subnet entries received from routers farther down the tree.
 - The Duetto code does not propagate static routes (static route redistribution) or subnets assigned to tunnels.
 - All subnets are propagated up the tree *including IPv4 subnets. Hence, the IPv6 manet also enabled IPv4 networking via IPv6 routing.*
 - Useful for use as remote configuration of the WMIC cards was only possible via IPv4 – the network interface on the cards was not IPv6 capable.
- “Duetto” code is experimental and not planned for production, however, much related work has spun off of the “Duetto” Code.
 - Nested Nemo Tree Discovery draft-thubert-tree-discovery-08.txt
 - 6LoWPAN Neighbor Discovery draft-ietf-6lowpan-nd-06
 - RPL: Routing Protocol for Low Power and Lossy Networks draft-ietf-roll-rpl-03
 - Industrial Routing Requirements in Low Power and Lossy Networks draft-ietf-roll-indus-routing-reqs-06

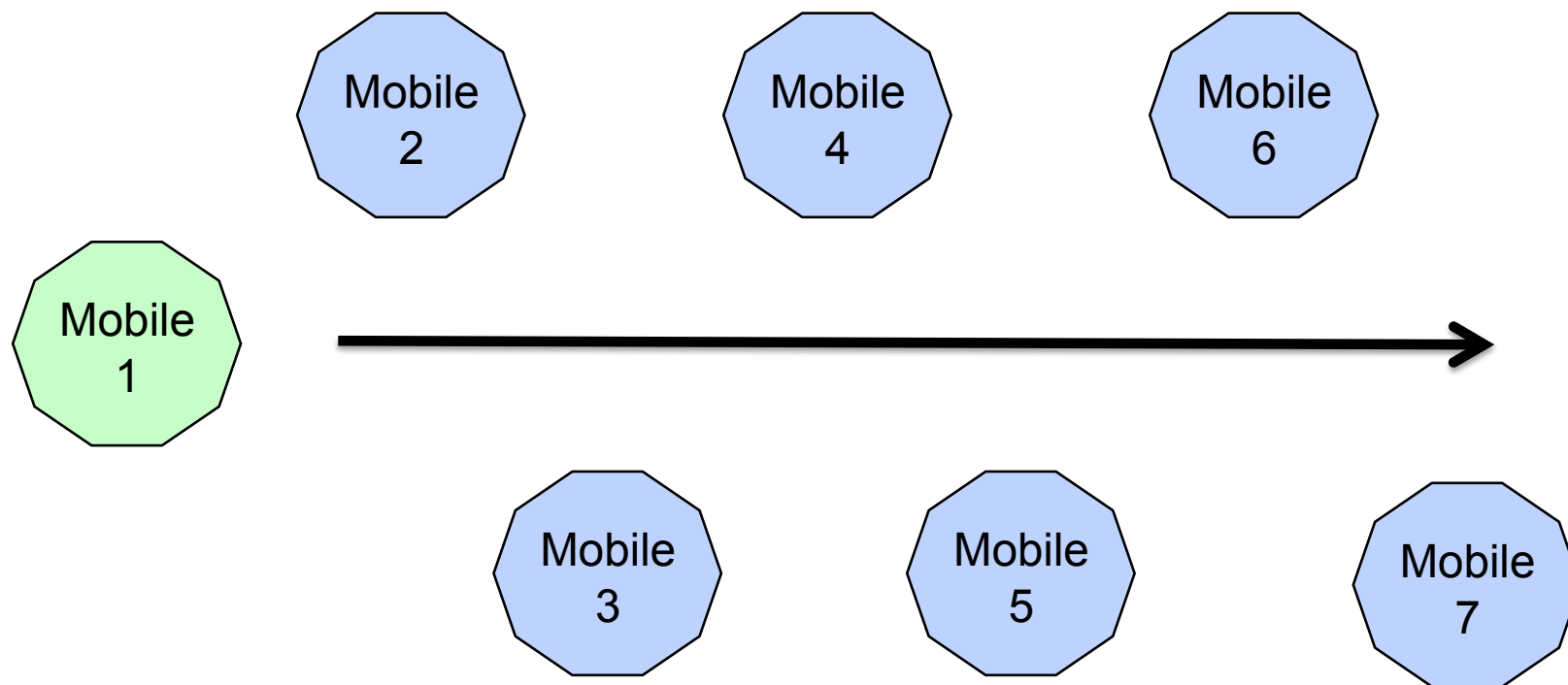


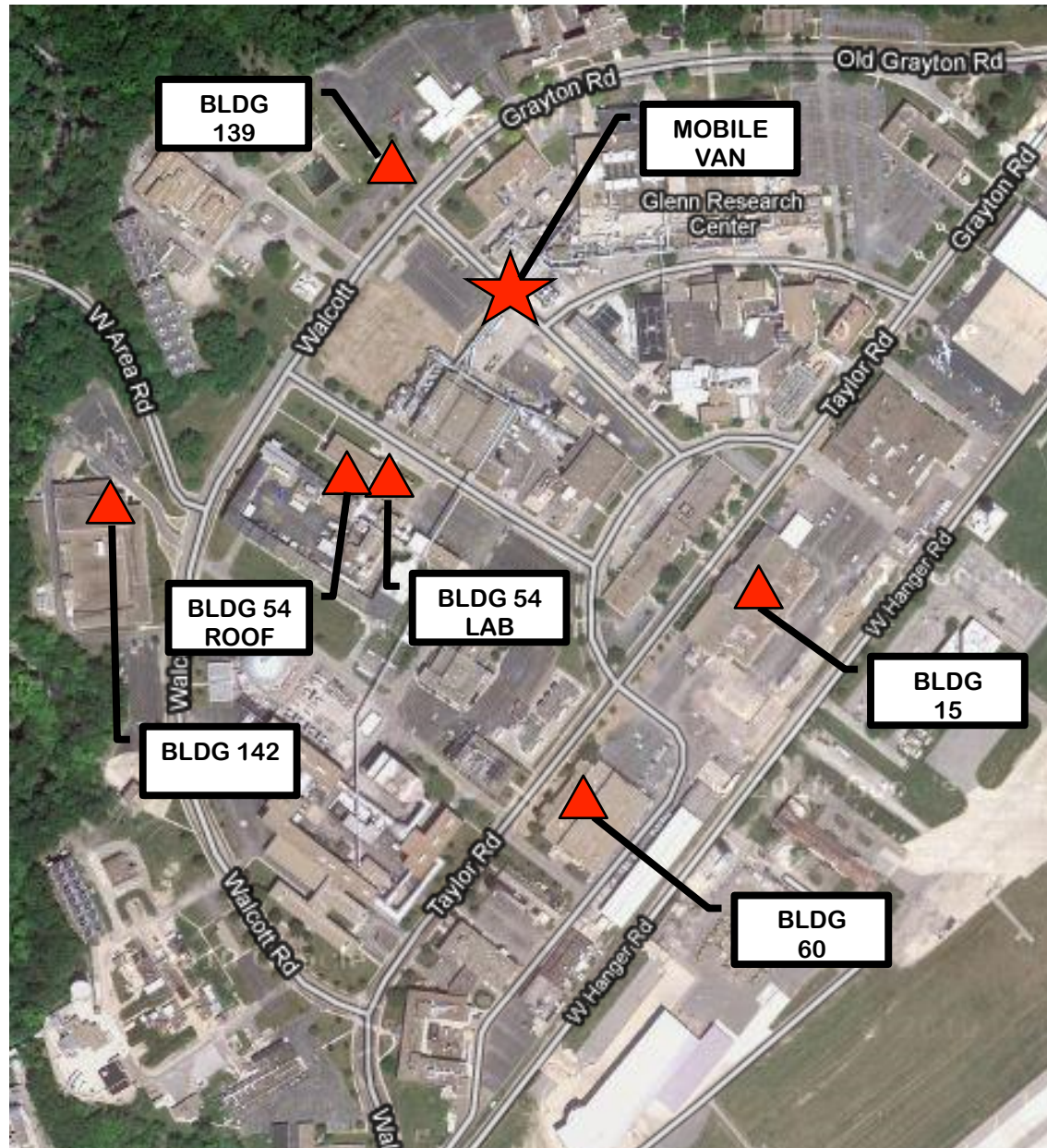
Network Monitoring

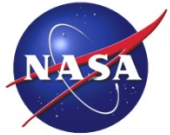
- Developed mapping tool to provide Network monitoring.
 - Need to be able to keep track of what is happening in the mobile network (what the current topology is)
 - Needed to troubleshoot the system
 - The duetto code did not support SNMP, so the perl script was written to SSH into each individual router and execute command line queries. The output of these queries were parsed and compared to get a picture of how the topology was connected.
 - The PERL script used Graphvis (<http://www.graphviz.org/>)
 - Available upon request.
- Everything was IPv6 Web Enabled
 - Network Monitoring
 - ArchRock sensor monitoring
 - IPv6 Webcam



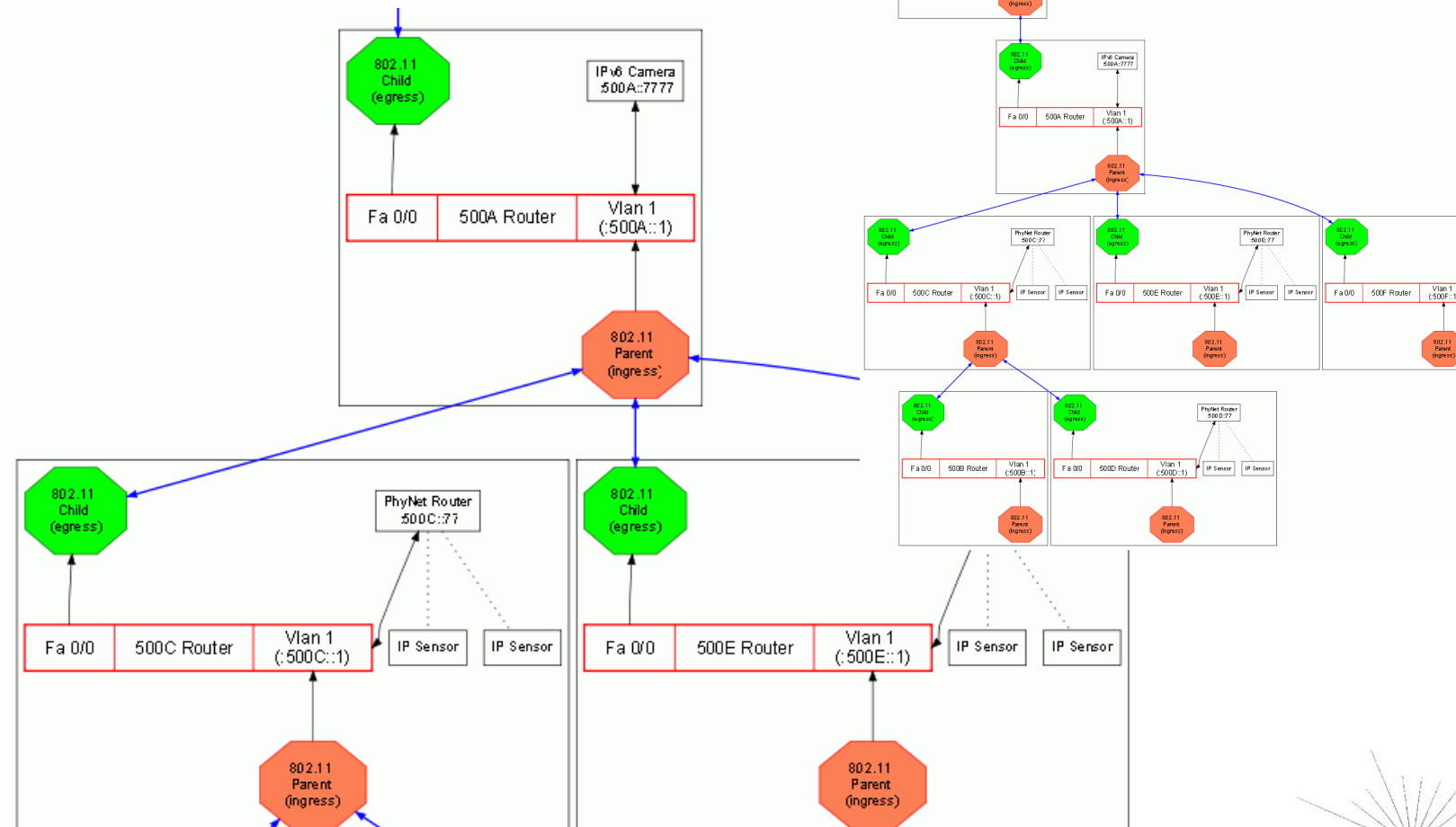
Field Test of Mobility





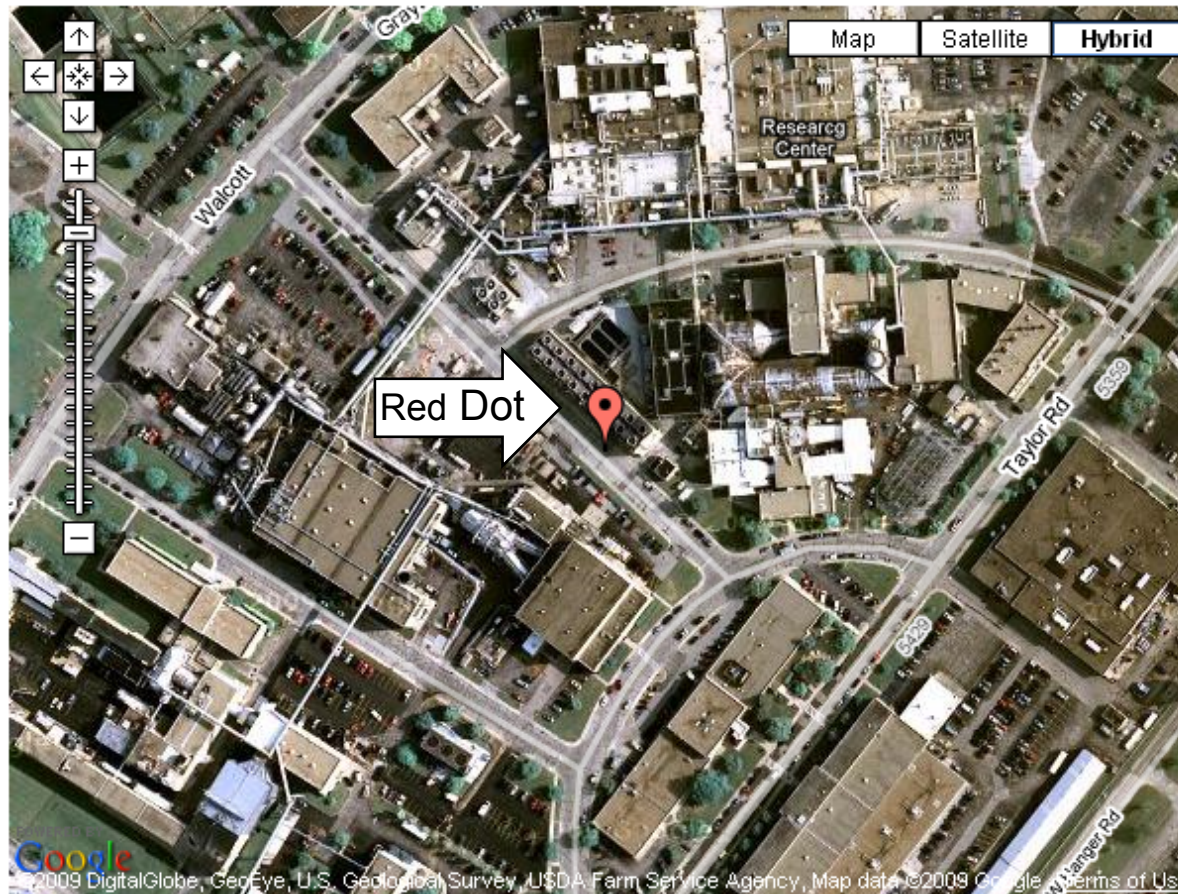


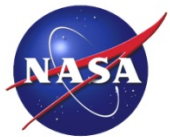
Dynamic Manet Topology (IPv6)





GPS location of 500C ACTS Van Node (IPv6)





ACTS Van's Guests WebCam (IPv6)

NetworkCamera

Pan / Tilt

Scan

Preset

1 2 3 4

5 6 7 8

-Preset-

Brightness

- STD +

Backlight

On Off

White Balance

Auto

Output

Open

Short

Refresh Rate

MJPEG

Resolution

320x240

Image Quality

Standard

Running in IPv6 mode.

Panasonic

Network Camera

English Français Deutsch Italiano Español Русский 简体中文 한국어 日本語

BB-HCM511A

Version 3.51R00

Running in IPv6 mode.



LowPAN Server (IPv6)

Home

Setup

Server

Routers

Nodes

Software Update

System and Network

Connectivity

Energy

Traffic

Reliability

Sensing and Control

Sensor/Actuator Devices

Sensor Data Analysis

Actuator Control

Data Export

Support

User Guide

Network Admin Guide

Developer Guide

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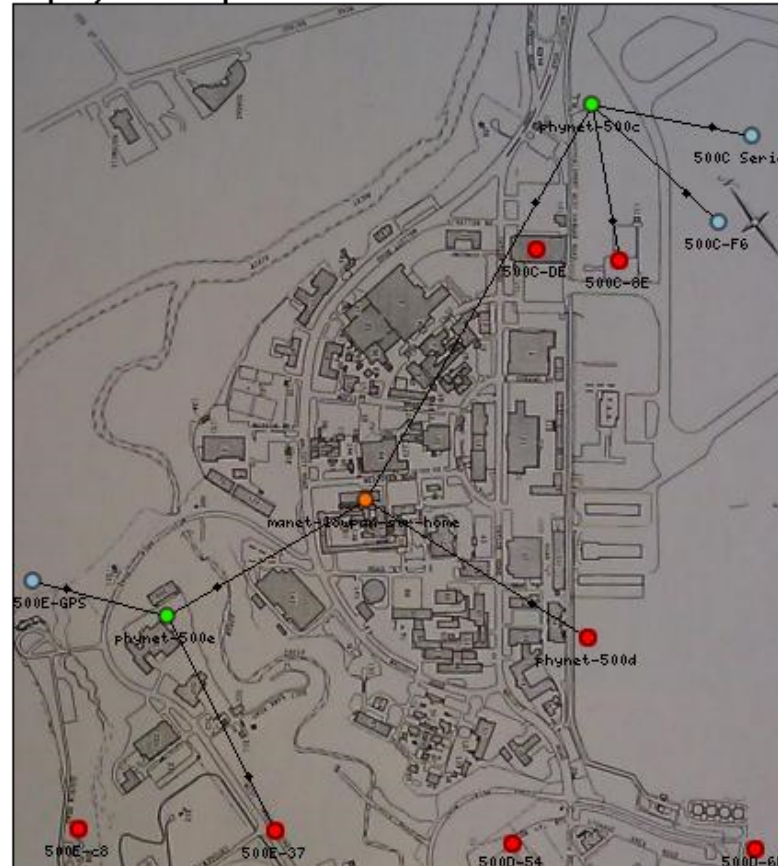
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Home

● Server ● Router ● Node ● Missing Router or Node

Deployment started on 2009-03-17 3:13:45 pm EDT, running for 211d 20h 33m 56s.

Deployment Map



Network Devices

13 Devices

● manet-lowpan-svr-home

● 500E-GPS

sensor data never heard
--- °F --- % --- lux --- lux

500C

● 500C-Serial

sensor data never heard
--- °F --- % --- lux --- lux

● 500C-8E

2009-10-12 2:30:11 pm EDT (3 days ago)
52.6 °F 67.6 % 150 lux 56 lux

● 500C-DE

sensor data never heard
--- °F --- % --- lux --- lux

● 500C-F6

11:45:53 am
51.7 °F 60.5 % 3 lux 0 lux
Low Battery: 2.59 V

● phynet-500c

11:46:58 am

500D

● 500D-54

sensor data never heard
--- °F --- % --- lux --- lux

● 500D-6F

sensor data never heard
--- °F --- % --- lux --- lux





Node 500C – Mobile Van Sensors

500C-F6

Group: 500C

Description:

[Edit Node Information](#)

Last Heard: 11:45:58 am

Sensing and Control

[Serial Interface](#)

[Energy](#)

[Node Management](#)

Sample Period (in seconds): 31 [\[edit\]](#)

[Enable All Internal Sensors](#)

[Disable All Internal Sensors](#)

Last Sample: 11:45:53 am [Request New Sample Now](#)

Sensor

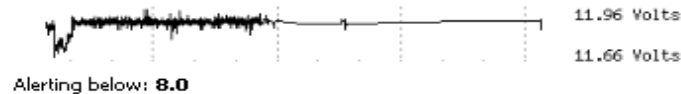
Value

[15 minutes](#) [1 hour](#) [6 hours](#) [1 day](#)

ADC0

11.84 Volts

[Rename Device](#)
[Configure Device](#)
[Calibrate Device](#)
[Alert Thresholds](#)
[Disable Device](#)



Humidity

60.5 %

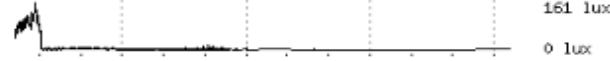
[Rename Device](#)
[Alert Thresholds](#)
[Report Thresholds](#)
[Disable Device](#)



Light (PAR)

3 lux

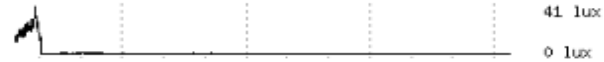
[Rename Device](#)
[Alert Thresholds](#)
[Report Thresholds](#)
[Disable Device](#)



Light (TSR)

0 lux

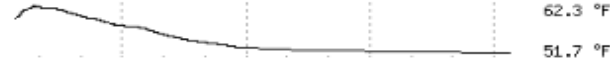
[Rename Device](#)
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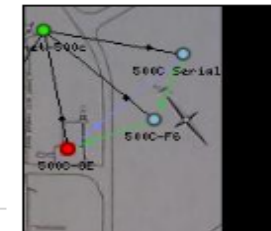
Temperature

51.7 °F

[Rename Device](#)
[Alert Thresholds](#)
[Report Thresholds](#)
[Disable Device](#)



Oct14 05:00pm Oct14 11:00pm Oct15 05:00am Oct15 11:00am



[Edit Node Location](#)

Servers

[manet-lowpan-svr-home](#)

Parent Nodes

Signal

[phynet-500c](#)

-33 dBm

[500C Serial](#)

-32 dBm

Child Nodes

Signal

None

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Summary/Conclusions

- A two-tier sensor network was successfully demonstrated that utilized an ad hoc mobile network to handle mobility and a 6LowPAN sensor network to provide sensor readings.
 - The entire system operated using IPv6 technology.
 - An IPv4 mobile network could be constructed but only if IPv6 was operational as IPv6 neighbor discovery is used to discover and construct the ad hoc network.
- A parent/child system was used in this network. Such a system could result in mobile ad hoc router pairs becoming isolated. Therefore, some interaction between the layer-3 mobile ad hoc networking code and the radio system should be considered to help alleviate this problem.
- There continues to be a need for a radio that is developed specifically to work with layer-3 ad hoc and mobile networking
 - Most current radios system counteract rather than compliment layer-3 ad hoc routing protocols.